Claims

1. A communication control apparatus, comprising:

a storage device for storing search information to determine a subsequent transfer route for a packet received by way of its destination address; and

a route search device to search for a transfer route for said packet received based on said search information, wherein said search information is associated with a tree structure, each node in said tree structure having at least one entry, a mask prefix associated with said at least one entry, wherein each entry includes information on the number of bits of said mask prefix associated therewith, and a sort key, and wherein the number of bits of said sort key is set to be greater than or equal to the longest mask length amongst the mask lengths of all said mask prefixes;

a bit string divided into an upper side bit string field and a lower side bit string field, wherein the upper side bit string field of each of said sort keys is to match said mask prefix associated with an entry having said sort key wherein entries are assigned to predetermined nodes of said tree structure based on the sort order of their sort keys; each node having an entry list in which multiple entries included therein are sorted based on their sort keys; and each node except leaf nodes are linked via each branch to relate each entry in the entry list of said node to each node at the next lower hierarchy.

2. The communication control apparatus according to claim 1, wherein said route search device further comprises:

means for extracting the destination address of said packet received;

means for searching each search target node for an entry having information on a mask prefix that matches the upper side bit string field of the extracted address in said search target node, as a matching entry to determine if there is only one matching entry, said matching entry becoming the inside-node matching entry and determine if there are multiple matching entries an entry having information on the mask prefix with the longest mask length amongst the matching entries to become the inside-node matching entry;

search control means for specifying a search target node to said inside node matching entry search means, said search control means selecting a link based on a comparison of the sort key of each entry in each of said search target nodes with the extracted address to select a node related to the selected link to become the next search target node, and determine that the node-by-node search process is terminated if said link does not exist; and

means for determining a transfer route for the packet received related to the extracted address based on a mask prefix with the longest mask length amongst the mask prefixes associated with multiple inside-node matching entries related to the extracted address, after the node-by-node search process terminates.

3. The communication control apparatus according to Claim 2 wherein when a branch is linked to a node at the next lower hierarchy, two branches will be associated with an entry at one end of the entry list of the node and one branch will be associated with each of the remaining entries.

4. The communication control apparatus according to Claim 1 further comprising a means for constructing said tree, said means for constructing a tree comprising:

means for calculating minimum and maximum values of said sort key which are associated with a mask prefix C, as C_{s_min} and C_{s_max}, respectively;

means for setting said sort key C_s to be associated with said mask prefix C fulfilling the condition $C_{s\_min} \leq C_s \leq C_{s\_max}$; and

means for determining an entry for each node based on said sort key set for each mask prefix by said sort key setting means to generate said tree structure based on said determination.

5. The communication control apparatus according to Claim 4 further comprising sort keys stetting means, wherein said sort keys associated with two mask prefixes C_1 and C_2 are C_{1s} and C_{2s}, the minimum sort keys being associated with C_1 and C_2 are C_{1s_min} and C_{2s_min}, and the maximum sort keys being associated with C_{1s_max} and C_{2s_max}, respectively; and wherein when $C_{1s\_min} \leq C_{2s\_min} \leq C_{2s\_max} \leq C_{1s\_max}$ is satisfied with the exclusion of $C_{1s\_min} = C_{2s\_min} = C_{2s\_max} = C_{1s\_max}$, said sort keys means set C_{1s} within a range from C_{1s_min} to C_{1s_max} and beyond the range, from C_{2s_min} to C_{2s_max}.

6. The communication control apparatus according to Claim 4 wherein said tree structure constructing means outputs said tree structure in which sort keys that are derived from the same mask prefix are streamlined leaving only one sort key derived from the same mask prefix at each leaf node.

7. The communication control apparatus according to Claim 1 wherein a mask prefix with a bit length of 1 and a bit value 0 and a mask prefix with a bit length of 1 and a bit value 1 are included in the mask prefix associated with at least one entry; and a mask prefix with a bit length of 1 and a bit value 0 or a mask prefix with a bit length of 1 and a bit value 1 is associated with a default transfer route.

8. A communication control apparatus comprising:

means for storing mask prefix information including information related to a mask

prefix with a bit length of 0, the mask prefix with a bit length of 0 set to be associated with a default transfer route;

means for extracting a destination address from the packet received;

means for searching a mask prefix having the longest bit length amongst the mask prefixes matching an upper continuous bit string (UCS), said UCS corresponding to the most significant bits (MSB) of the bit string of the extracted destination address; and

means for determining a transfer route for the packet received related to the currently extracted destination address based on the selected mask prefix.

9. A communication control apparatus comprising means for storing mask prefix information including information related to:

a) a mask prefix with a bit length of 1 and a bit value 0 and a mask prefix with a bit length of 1 and a bit value 1;

b) a mask prefix with a bit length of 1 and a bit value 0 or the mask prefix with a bit length of 1 and a bit value 1; and

c) a mask prefix with a bit length of 0 being set to be associated with a default transfer route;

means for extracting a destination address from a packet received;

means for searching a mask prefix with the longest bit length amongst the mask prefixes matching the upper continuous bit string field as the selected mask prefix; and

means for determining a transfer route for the packet received related to the currently

extracted address based on the selected mask prefix.

10. A communication control apparatus comprising:

a storage device for storing search information to determine the next transfer route for a packet received by way of its destination address; and

a route search device to search for a transfer route for the packet received based on said search information, wherein

said search information is comprised of a first and second information field, wherein said first and second information fields are based on a predetermined integer u, to define respective bit numbers of a mask prefix arranged in descending order from the MSB to the LSB, a short and a long mask prefix consisting of at most u bits and a mask prefix consisting of at least (u+1) bits, referred to as a short mask prefix and a long mask prefix, respectively;

an upper side mask prefix field from the first bit to the u^{th} bit and a lower side mask prefix field from the $(u+1)^{th}$ bit to the last bit of said mask prefix, said long mask prefix having the same upper side mask prefix field forming a mask prefix group and said first information field includes information related to the short mask prefix and the upper side mask prefix field,

said first information field is stored in a table, said table including: a) u-bit entries with sort keys different from one another; b) entries in each table that include first and second table entries; c) all the bits from the first to the w^{th} bit (where $w \leq u$ is an integer) of the sort key of the first table entry that are identical to the short mask prefix associated with the first table entry; and d) all the bits of the sort key of the second table entry that are identical to the upper side mask prefix field associated with the second table entry;

said second information field includes information related to the lower side mask prefix field, said second information field is stored in at least one tree structure, each tree structure is associated with each mask prefix group, and where a link is established to the tree structure from an entry having a sort key equal to the upper side mask prefix field of a long mask prefix belonging to the associated mask prefix group and included in said table, each node in each tree structure has at least one entry, the lower side mask prefix field of each long mask prefix is associated with at least one entry, each entry in the tree structure includes information on the number of bits of the lower side mask prefix field associated therewith, and a sort key; and wherein

the number of bits of an entry in the tree structure is set to be greater than or equal to the longest lower side mask prefix field amongst the lower side mask prefix field mask lengths of all the lower side mask prefix fields;

the upper side bit string field of each sort key is set to match the lower side mask prefix field associated with an entry having said sort key; entries are assigned to predetermined nodes of said tree structure based on the sort order of their sort keys; each node having an entry list in which multiple entries included therein are sorted based on their sort keys; each node except leaf nodes being linked via each branch related to each entry in the entry list of the node to each node at the next lower hierarchy;

said route search device comprising:

means for extracting the destination address of a packet received from the packet received;

a table route search device, wherein a bit string field from the first to the u^{th} bits and a bit string field of $(u+1)^{th}$ bit and subsequent bits, said table route search device

searching for a transfer route for the packet received related to the currently extracted address by comparing each entry in the table with the first extracted address field;

a tree structure route search device searching for a transfer route for the packet received based on the currently extracted address by comparing each entry in the tree structure with the second extracted address field;

a controller for controlling said table route search device and said tree structure route search device; and

means for determining the transfer route for the packet received related to the currently extracted address based on search results of said table route search device and said tree structure route search device;

said table route search device comprising:

means for searching for an entry having a sort key matching the upper side bit string field of the first extracted address field as a matching entry; and

means for notifying said controller of the linked tree structure if a link from the appropriate entry retrieved by said search means to a predetermined tree structure is set;

said tree structure route search device comprising:

inside-node matching entry search means for searching each search target node of said tree structure for an entry having information on the lower side mask prefix field that matches the upper side bit string field of the second extracted address field in the search target node as a matching entry to determine if there is only one matching entry, the only one entry to become the inside-node matching entry and determine if there are

multiple matching entries, an entry having information on the lower side mask prefix field with the longest bit length amongst the matching entries to become the inside-node matching entry;

search control means for specifying a search target node to said inside-node matching entry search means, the search control means selecting a link based on a comparison of the sort key of each entry in each of said search target node with the second extracted address field to determine a node related to the selected link to be the next search target node and determining that the node-by-node search process is terminated if said link does not exist; and a lower side mask prefix field determining means for determining the lower side mask prefix field with the longest bit length amongst the lower side mask prefix field corresponding to multiple inside-node matching entries related to the second extracted address field after the node-by-node search process is terminated;

said controller comprising:

first directing means for directing the table route search means to execute a search process for the currently extracted address which has been extracted by said address extracting means prior to directing said tree structure route search means; and

second directing means for directing said tree structure route search means to execute a search process related to the currently extracted address by specifying the search target tree structure notified by said notification means, when notified by said notification means of said table route search means; and

final determination means for determining a transfer route for the packet received based on its currently extracted address utilizing the short mask prefix related to the appropriate entry retrieved by said search means of said table route search means, if said second directing means does not direct said tree structure route search means to execute a search process; and determining if said second directing means directs said tree

structure route search means to execute said search process, a long mask prefix which is based on the upper side mask prefix field related to an entry in the link-source table in the tree structure, which was determined to be the search target tree structure by said tree structure route search means, and the lower side mask prefix field determined by said lower side mask prefix field determining means of said tree structure route search means to be a transfer route for the packet received related to the currently extracted address.

(11) A communication control method for storing search information to determine the next transfer route for a packet received based on its destination address, and searching for a transfer route for the packet received based on said search information, wherein

said search information is associated with a tree structure; each node in the tree structure having at least one entry; each mask prefix being associated with at least one entry; each entry including information on the number of bits of a mask prefix associated therewith, and a sort key; the number of bits of the sort key being set to be greater than or equal to the longest mask length amongst the mask lengths of all the mask prefixes; the upper side bit string field of each sort key being set to match the mask prefix associated with the entry having the sort key; entries being assigned to predetermined nodes of said tree structure based on the sort order of the sort keys; and each node having an entry list in which multiple entries included therein are sorted based on their sort keys; each node except leaf nodes being linked by a branch related to each entry in the entry list of the node to each node at the next lower hierarchy;

the communication control method comprising the steps of:

extracting a destination address of a packet received from the packet received based on its destination address;

searching for each search target node of an entry having information on a mask prefix

that matches the upper side bit string field of the extracted address in the search target node, as a matching entry to determine if there is only one matching entry, the only one matching entry to become the inside-node matching entry, and to determine if there are multiple matching entries, an entry having information on a mask prefix with the longest mask length amongst the matching entries to become the inside-node matching entry;

determining a search target node at said inside-node matching entry search step, the search control step selecting a link based on a comparison of the sort key of each entry in each search target node with the extracted address to determine the node related to the selected link to be the next search target node and determining that the node-by-node search process is terminated if a link does not exist; and

determining a transfer route for the packet received based on its extracting address, said determination being based on a mask prefix with the longest mask length amongst the mask prefixes associated with multiple inside-node matching entries related to the extracted address, after the node-by-node search process is terminated.

(12) The communication control method according to Claim 11 wherein the same number of entries are set for each of nodes belonging to the same hierarchy of said tree structure.

(13) The communication control method according to Claim 11, comprising the steps of:

calculating the minimum and the maximum values of a sort key associated with a mask prefix C, as C_{s_min} and C_{s_max}, respectively;

setting a sort key C_s to be associated with the mask prefix C under a condition of $C_{s\_min} \leq C_s \leq C_{s\_max}$; and

determining an entry for each node based on a sort key set for each mask prefix at said

sort key setting step to generate a tree structure based on said determination.

(14) The communication control method according to Claim 11 wherein the tree structure in which the sort keys derived from the same mask prefix have been streamlined when the node at the lower hierarchy is outputted.

(15) The communication control method according to Claim 11 wherein a mask prefix with a bit length of 0 is included in the mask prefix associated with said at least one entry, and the mask prefix with a bit length of 0 is associated with a default transfer route.

(16) A communication transfer method comprising the steps of:

storing mask prefix information including information related to a mask prefix with a bit length of 0, the mask prefix with a bit length of 0 being set to be associated with a default transfer route.

extracting a destination address of a packet received from the packet received;

searching for a mask prefix with the longest bit length amongst the mask prefixes matching the upper continuous bit string field as a matching mask prefix when a continuous bit string field from the MSB in the bit string of an extracted address; and

determining a transfer route for the packet received related to the currently extracted address based on said mask prefix.

(17) A communication control method comprising the steps of:

storing mask prefix information including information related to a mask prefix with a bit length of 1 and a bit value 0 and a mask prefix with a bit length of 1 and a bit value 1, the mask prefix with a bit length of 1 and a bit value 0 or the mask prefix with a bit

length of 1 and a bit value 1, and a mask prefix with a bit length of 0 being set to be associated with a default transfer route;

extracting a destination address of a packet received;

searching for a mask prefix with the longest bit length amongst the mask prefixes matching the upper continuous bit string field as a matching mask prefix when a continuous bit string field from the MSB in the bit string of an extracted address is found; and

determining a transfer route for a packet received related to the currently extracted address based on the matching mask prefix.

(18) A communication control method for storing search information to determine the next transfer route for a packet received from its destination address, and searching for a transfer route for the packet received based on said search information, wherein

said search information is comprised of a first and a second information field; a predetermined integer u and respective bit numbers of a mask prefix arranged in the order from the MSB to the LSB; a mask prefix with at most u bits and a mask prefix with at least u+1 bits, referred to a short mask prefix and a long mask prefix, respectively; a field from the first to the u^{th} bits and a field from the $(u+1)^{th}$ to the last bit of the long mask prefix referred to the upper side mask prefix field and the lower side mask prefix field, respectively; long mask prefixes having the same upper side mask prefix field to form a mask prefix group; said first information field including information related to a short mask prefix and the upper side mask prefix field; said first information field being stored in a table; said table including u-bit entries with sort keys different from one another; the entries included in each table consisting of a first and a second table entries; all the bit values from the first to the w^{th} (where $w < u$ is an integer) of the sort key of the first table entry that are identical to the short mask prefix

associated with the first table entry; and all the bits of the sort key of the second table entry that are identical to the upper side mask prefix field associated with the second table entry; said second information field including information related to the lower side mask prefix; said second information field being stored in at least one tree structure; each tree structure is associated with each mask prefix group, and a link established to the tree structure from an entry having a sort key equal to the upper side mask prefix field of a long mask prefix belonging to the associated mask prefix group and included in said table; each node in each tree structure has at least one entry; the lower side mask prefix field of each long mask prefix is associated with at least one entry; each entry in the tree structure includes information on the number of bits of the lower side mask prefix field associated therewith, and a sort key; the number of bits of an entry in the tree structure is set to be greater than or equal to the longest lower side mask prefix field mask length amongst the lower side mask prefix field mask lengths of all the lower side mask prefix fields; the upper side bit string field of each sort key is set to match the lower side mask prefix field associated with an entry having the sort key; entries are assigned to predetermined nodes of said tree structure based on the sort order of their sort keys; each node has an entry list in which multiple entries included therein are sorted based on their sort keys; each node except leaf nodes are linked via each branch that are related to each entry in the entry list of the node to each node at the next lower hierarchy;

the communication control method comprising the steps of:

extracting a destination address of a packet received from the packet received;

searching for a transfer route for the packet received from its currently extracted address based on a comparison of each entry in the table with the first extracted address field wherein a bit string field from the first to the u^{th} bit and a bit string field of $(u+1)^{th}$ bits and subsequent bits are referred to as a first and a second extracted address field, respectively;

searching for a transfer route for the packet received from its currently extracted address based on a comparison of each entry in the tree structure with the second extracted address field;

controlling said table route search step and said tree structure route search step; and

determining a transfer route for the packet received from its currently extracted address based on search results of said table route search step and said tree structure route search step;

said table route search step comprising the steps of:

searching for an entry having a sort key matching the upper side bit string field of the first extracted address field as a matching entry; and

notifying said control step to that effect and the linked tree structure if a link from the appropriate entry retrieved at said search step to a predetermined tree structure is set;

said tree structure route search step further comprising the steps of:

searching each search target node of said tree structure for an entry having information on the lower side mask prefix field that matches the upper side bit string field of the second extracted address field in the search target node, as a matching entry to determine if there is only one matching entry, the only one matching entry to become the inside-node matching entry and determine if there are multiple matching entries, an entry having information on the lower side mask prefix field with the longest bit length amongst the matching entries to become the inside-node matching entry;

determining a search target node at said inside-node matching entry search step, the

search control step selecting a link based on comparison of the sort key of each entry in each search target node with the second extracted address field to determine a node related to the selected link to be the next search target node and determining that the node-by-node search process is terminated if a link does not exist; and

determining the lower side mask prefix field with the longest bit length among the lower side mask prefix field corresponding to multiple inside-node matching entries related to the second extracted address field, after the node-by-node search process is terminated;

said control step further comprising the steps of:

a first directing step for executing a search process at the table transfer search step for the currently extracted address which has been extracted at said address extracting step, prior to execution of a search process at said tree structure route search step;

a second directing step for directing said tree structure route search step to execute a search process related to the currently extracted address by specifying the search target tree structure notified by said notification step when notified by said notification step of said table route search step; and

determining a transfer route for the packet received related to the currently extracted address, based on the short mask prefix related to the appropriate entry retrieved at the search step of said table route search step if execution of a search process at said tree structure route search step has not been directed at said second directing step; and

determining a long mask prefix based on the upper side mask prefix field related to an entry in the link-source table in the tree structure determined to be a search target tree structure by said tree structure route search step and the lower side mask prefix field determined by said lower side mask prefix field determining step of said tree structure

route search step to be a transfer route for the packet received related to the currently extracted address if execution of a search process at the tree structure route search step has been directed at said second directing step.

(19) A data structure for communication control, related to search information for determining the next transfer route for a packet received, from the destination address of the packet received comprising:

said search information associated with the tree structure; each node in the tree structure having at least one entry; each mask prefix being associated with at least one entry; each entry including information on the number of bits of a mask prefix associated therewith, and a sort key; the number of bits of the sort key being set to be greater than or equal to the longest mask length amongst the mask lengths of all mask prefixes; The upper side bit string field of each sort key being set to match a mask prefix associated with an entry that has the sort key; entries being assigned to predetermined nodes of said tree structure based on the sort order of their sort keys; each node having an entry list in which multiple entries included therein are sorted based on their sort keys; and each node except leaf nodes being linked via each branch related to each entry in the entry list of the node to each node at the next lower hierarchy;

(20) The data structure for communication control according to Claim 19 wherein the same number of entries are set for each of nodes belonging to the same hierarchy in said tree structure.

(21) The data structure for communication control according to Claim 19 wherein two branches are associated with an entry at one end of the entry list of the node, and one branch is associated with each of the other entries for a node linked to a node at the next lower hierarchy via a branch.

(22) A program storage device readable by machine, tangibly embodying a program of

instructions executable by the machine to perform method steps for providing a communication control method for storing search information to determine the next transfer route for a packet received based on its destination address, and searching for a transfer route for the packet received based on said search information, wherein

said search information is associated with a tree structure; each node in the tree structure having at least one entry; each mask prefix being associated with at least one entry; each entry including information on the number of bits of a mask prefix associated therewith, and a sort key; the number of bits of the sort key being set to be greater than or equal to the longest mask length amongst the mask lengths of all the mask prefixes; the upper side bit string field of each sort key being set to match the mask prefix associated with the entry having the sort key; entries being assigned to predetermined nodes of said tree structure based on the sort order of the sort keys; and each node having an entry list in which multiple entries included therein are sorted based on their sort keys; each node except leaf nodes being linked by a branch related to each entry in the entry list of the node to each node at the next lower hierarchy;

said communication control method comprising the steps of:

extracting a destination address of a packet received from the packet received based on its destination address;

searching for each search target node of an entry having information on a mask prefix that matches the upper side bit string field of the extracted address in the search target node, as a matching entry to determine if there is only one matching entry, the only one matching entry to become the inside-node matching entry, and to determine if there are multiple matching entries, an entry having information on a mask prefix with the longest mask length amongst the matching entries to become the inside-node matching entry;

determining a search target node at said inside-node matching entry search step, the search control step selecting a link based on a comparison of the sort key of each entry in each search target node with the extracted address to determine the node related to

the selected link to be the next search target node and determining that the node-by-node search process is terminated if a link does not exist; and

determining a transfer route for the packet received based on its extracting address, said determination being based on a mask prefix with the longest mask length amongst the mask prefixes associated with multiple inside-node matching entries related to the extracted address, after the node-by-node search process is terminated.